Isochronicity Correction for Mass Measurements in CR

H. Weick[1], *S. Litvinov*[1], *D. Toprek*[2], *A. Dolinskii*[1]

[1]GSI, Darmstadt, Germany ; [2] VINCA Belgrade, Serbia

Isochronous mass measurements in the CR by the ILIMA collaboration are a part of the initial experimental programme of FAIR. With higher primary beam intensities and higher acceptance of the Super-FRS also the CR in isochronous mode aims at acceptances of 100 mm mrad in vertical and horizontal plane combined with a momentum acceptance of $\delta = \pm 0.5\%$. This is about a factor 500 higher than the acceptance of the present ESR. The sufficient isochronicity to obtain the needed mass resolution of about $\Delta m/m = 10^{-6}$ requires a dedicated correction scheme.

Past studies have shown that path length differences, which are described by the first order coefficients of the transfer matrix of the ring system, are easily compensated by having an overall achromatic system. However, for large emittance the 2nd order contributions already become so huge that the goal in $\Delta m/m$ or acceptance would be far away [1]. Still in an overall bend system with help of symmetric imaging a higher order correction is possible. However, this would violate the stability criteria of non-zero phase advance for a storage ring [2]. As a way out we have found a partial correction. For this time aberrations are divided into contributions with varying size but fixed amplitude and others with increasing absolute sum over many turns. Only the growing contributions need to be corrected as the others will become small in relative time deviation ($\Delta t/t$) over many turns.

With the help of symplectic relations [2] we could show that in a 2nd order transfer matrix all quadratic contributions to $\Delta t/t$ converge to zero with a sextupole correction that corresponds to the well-known chromaticity correction of the tune. In a mirror symmetric ring this requires only two sextupole families for each horizontal and vertical plane. A third independent sextupole is required for shaping the dispersion curve in the arc to provide the proper detour for faster ions to compensate the velocity dependence in 2nd order. The resulting sextupole strengths are well within the present specifications. A fourth sextupole could correct higher order mismatch of dispersion.

Figure1 shows a Monte-Carlo simulation with the MOCADI code [3] for the full acceptance of the CR. With a correction by three or four sextupole families a fast convergence to a low limit in $\Delta t/t$ is given. This limit corresponds to higher orders of chromaticity. In principal this could also be corrected with octupoles.

In addition the influence of fringe fields and field inhomogeneities was studied. Based on realistic field calculations one can see that extended fringe fields cause a smaller shift in the tunes and lead to larger higher order geometrical time aberrations. Dipole inhomogeneities are very critical. At maximum field strength of 1.6T the CR dipole will have a field deviation of,

$$\Delta B/B(x) = 1.15\,(x/\rho)^2 + 0.2\,(x/\rho)^3 + 568\,(x/\rho)^4$$

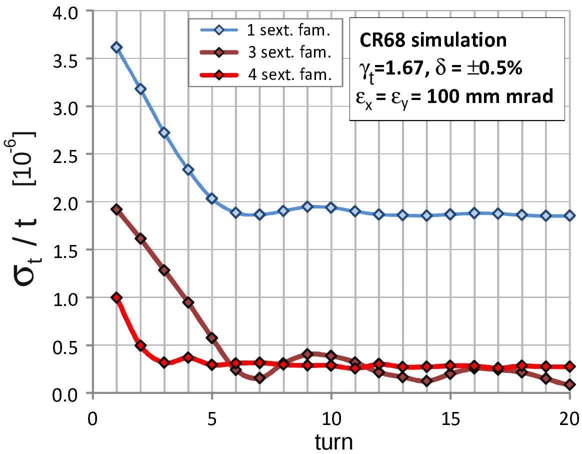

Figure 1: MOCADI simulation of time deviations as function of turns for the full CR acceptance, for corrections with different number of sextupole families.

with (x) being the distance from the optical axis (x_{max}=19cm) and ρ the radius of curvature (ρ=81.25cm).

The large sextupole component requires a completely different adjustment of the other explicit sextupoles in the ring, yet it is possible. Then the remaining 4th order contribution dominates the time deviations.

The calculation in Figure 2 shows a direct correspondence between the time deviations and the field distribution after correction of lower order terms. For further correction one decapole magnet at maximum dispersion would be required.

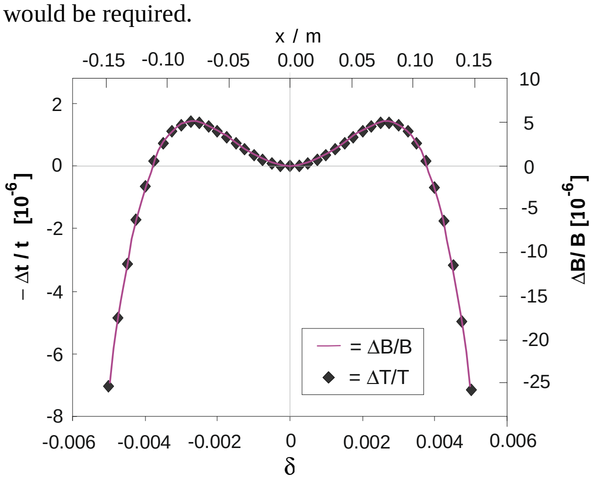

Figure 2: Direct correspondence between time deviations as function of relative momentum deviation (δ) and field shape as function of position (x).

References

[1] A. Dolinskii et al., NIM A 574 (2007) 207.
[2] H. Wollnik, NIM A 298 (1990) 156.
[3] N. Iwasa et al., NIM B 269 (2011) 752.